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ABSTRACT

This publication is the final report of the activities performed in the development of an introductory astronomy course operated in a competency based mode. The objective was for the course to be completely opposite from one which emphasizes memorization of factual knowledge. Instead, the student was to be involved in activities where he or she would have to solve problems in a fashion analogous to that of a working scientist. The report discusses the structure of the new course, the bookkeeping system and procedure for evaluation. The report also includes results of evaluation of student populations, relative merits of the new course versus the old, student attitudes, and costs of operating the new course. (Author/GA)

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DEPARTMENT OF

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ASTRONOMY

RICE UNIVERSITY
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SE 025 344

A COMPETENCY-BASED SELF-PACED ASTRONOMY COURSE FOR LIBERAL ARTS STUDENTS

FINAL REPORT

August 1975

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This is the final report of the activities performed under the grant of the above title, grant number OEG-O-74-3548 form the U.S. Office of Education, Department of Health, Education, and Welfare. However, the opinions expressed herein do not necessarily reflect the position or policy of the U.S. Office of Education, and no official endorsement by the U.S. Office

I. SUMMARY

This was a project to develop an introductory astronomy course which operated in a competency based mode. The objective was for the course to be completely opposite from one which emphasizes memorization of factual knowledge. Instead, the student was to be involved in activities where he would have to solve problems in a fashion analogous to that of a working scientist. One goal of the project was to compare the amount of factual knowledge gained by the students in this new course with that of another group of students in a more traditionally operated course.

The new course which was developed and operated during this project was successful, though many areas will require improvement. The students did indeed learn as much factual knowledge as those in the more traditional course. Several of the activities which were developed were very sucessful; they drew the student through a set of exercises in which he faced problems similar to those of the professional scientist Many of the activities had flaws in their design, and these either slowed down students or caused them to be disenchanted with the activities. These problems produced an overall rating for the new course which was a little lower than the older course.

The costs for operating the new course were appreciably larger than the older course; however, much of that was attributable to the problems with some of the units.

Next academic year we plan to further develop the more successful parts of the new course. In order to make the demands on the instructor's time be more reasonable, this new format will be used for only a single semester course instead of two semesters as done last year.

II. ACTIVITIES UNDERTAKEN

A. THE CONTEXT WITHIN WHICH THE PROJECT WAS CONDUCTED

The project was to experiment with an introductory course in astronomy for non-science students. The object was to develop a course in which these students would achieve confidence in their use of scientific material and to induce in them a degree of recall knowledge of facts without it being an objective stated to them.

The old version of the "course" was a pair of one semester courses which had been taught by the project director for the two prior years. It was a fairly traditionally run "Keller Plan" course employing the textbook Exploration of the Universe, Second Edition by G. Abell and a study guide developed by the project director. During the project this old version of the course was used to teach one section of students (about 60 students) and the course being developed in this project was taught to a second section of students (about 30). The first section will be referred to as I-hour (after the symbol used to denote the scheduled time) and the second section will be referred to as K-hour.

The I-hour course consisted of 15 Units each semester. The Units had to be completed in prescribed order and the Unit Tests were mastery tests -- 100% score was required and the student could take as many versions as required with no penalty. Tutors (or Proctors as some Instructors call them) were used to grade the Unit Tests and to provide help to the students. There were 10-12 students assigned per Tutor. The Tutors received credit for a senior level course entitled "Science Teaching"; they were students who took the course the preceding year.

In addition to the Unit Tests there were two so-called Review Units, after Units 5 and 10. These were graded by the instructor (the project director) and there was no mastery requirement on these. The semester course grade was determined by a formula involving the number of Units completed and the percentage grade on the Review Units -- the latter playing a fairly small role.

The Unit Tests and Review tests for the older I-hour version were mostly oriented towards factual knowledge (recall of definitions) and testing for skills to work problems analogous to those assigned in the Study Guide.

The content of the two semesters were divided as follows: The first semester covered historical aspects of astronomy, basic physics, instruments, and the solar system (excluding the sun). The second semester covered the sun, stars, galaxies, and cosmology. Each year several students have come into the course in the second semester, and it was therefore structured so that it depended little on the first semester.

Below we describe the new version of the course. Attached as Appendicies A and B are one Unit from each version which covered the same topic -- astronomical instruments. These illustrate some of the differences in the two versions.

B. STRUCTURE OF NEW COURSE

The ideals towards which this version of the course was designed were the following: The student will never be told to memorize anything and the Tests will not test for memorized knowledge; the Unit activities will be projects or exercises which the student is challenged to do, and success will be measured by the student demonstrating that he has performed the activity. The objective was for the student to do science rather than learn science. The topics covered in the two semesters were the same as in the older course. The activities involved the use of supplementary materials supplied in the Study Guide and material in the library such as professional astronomical literature.

The K-hour version of the course which was developed consisted of 17 Units each semester. In the first semester there were no Review Units. The Units had to be done in prescribed order except for the last 3 which could be done in any order. The grade was based on the number of Units completed.

In the second semester a more satisfactory format was achieved. There was a first set of 6 Units which had to be done in prescribed order, and this was followed by a Review Test. These 6 Units covered (albeit in a cursory fashion) the entire subject matter. The remaining II Units could be done in almost any order (some had other as prerequisites) and this allowed students to pick topics they found most interesting.

The K-hour also operated with Tutors to handle the grading of the Units Mastery Tests. There were 7-8 students per Tutor. Each Unit consisted of activities for the student to do followed by a Unit Mastery Test. For about a third of the Units each semester the activities were exercises which could be done through the study of a text (the units were designed to be essentially free of any specific text -- some students used the Abell text, others used a less extensive text by P. Hodge entitled Concepts of Contemporary Astronomy). The remainder of the Units consisted of activities which involved the use of supplementary materials supplied in the Study Guide; photographs, tables, catalogues and atlases in the library; or articles in the professional astronomical literature.

In some cases the student's work on the activities was directly checked by the Tutors (student would turn in reports or answers to some problems). In most cases, however, the activities were checked by the Unit Mastery

Test (UMT). The UMT, for example, would consist of a test on which the student could use the write up of his work in the library or lab exercise. If he had done the activity in an adequate fashion, he would be able to answer the questions easily; if not, he would have trouble. By this technique it was possible to "spot check" the student's work on the activities, and thereby minimize the time required by the Tutors to grade. There were two safeguards to prevent one student from using the work of another to answer a UMT without having done the work himself: first, Rice University has a very successful Honor System which works, and such an event is highly unlikely; and second, the Tutors always ask spot questions orally when grading written UMT's -- they spot incomplete understanding this way (100% written answers were not sufficient).

In addition to the questions on the UMT's which simply checked the performance of the student on the assigned activities, there were frequently questions which check the students understanding of concepts or ability to transfer what they had learned to different problems. Inevitably this occasionally involved terminology which the student needed to have learned, and so in part these questions tested recall knowledge. This, however, was avoided as much as possible in the K-hour section.

C. BOOKKEEPING SYSTEM

In order to keep track of how each student performed on questions of various types, an automated bookkeeping system was created which allowed analysis of each response on each Unit Test.

Every question on every version of each Unit Test in each section was categorized into one of three Question Types:

2 - Tests mathematical skills
4 - Tests for simple recall knowledge, non-math.
6 - Tests for ability to apply concepts and use facts, but not recall of facts.

Of course, these classifications are not always clear-cut. The student might have to recall some mathematical fact before he could answer a type 2 question, or for a type 6 question he might have to recall a method of analyzing a problem even though the factual data required to work the problem were given. Furthermore, the nature of the recall knowledge (Type 4) was somewhat different for the two versions.

Every time a student completed a Unit Test (whether he passed the Unit or not), the following data was recorded onto a computer card called an ACTION card:

Student's name (a 7 character standard form)
date
Unit number
Version of the Test (there were usually 4 prepared versions -- no student ever required more than 3 tries)
A code for each question on the Test indicating whether it was answered correctly or not.

These ACTION cards were read into a computer program which updated two sets of tables. One set is a ROLLFILE which contains the following information for each student:

A. Student's name
B. Parameter set. Up to 8 parameters could be defined. We have only used these six:
   1. Tutor identification
   2. Student's major field
   3. Student's class year
   4. Student's prior math/science preparation
   5. Number of other math or science courses taken that semester
   6. A code to indicate major extra-curricular activities (athletics, jobs, etc.)
C. Number of Units passed
D. Number of times that Unit Tests were attempted for each Unit
E. Number of times the student answered correctly or incorrectly questions of the three separate Question Types

The second set of tables is an EXAMFILE which keeps tally of the following information for each individual question on each version of each Unit test:

A. Question Type Category
B. Number of correct answers
C. Number of incorrect answers

The program updated these two files and then printed out summary information about each student and each test question. The ROLLFILE and the EXAMFILE were also used as input to other computer programs which produce correlations between variables or various other kind of statistical comparisons.

The summary information from the ROLLFILE was a useful tool for the Instructor and Tutors to monitor how the students were progressing. The EXAMFILE summary provided the instructor with information which allowed the detection of poor test questions and defects in the Study Guide.

D. PROCEDURE FOR EVALUATION

The Project was evaluated three ways:

1) By studying the performance of the students in the two sections on their respective Unit Tests. There were a few questions on the two sets of tests which were identical, but these formed such a small sample that the most satisfactory procedure was to classify the questions into the 3 Question Types and then compare student performance on the 3 Types.

2) There were pre- and post-tests administered to both sections -- the same tests to both sections. These contained, for the most part, questions on math skills and recall knowledge. These were not the objectives stated to the K-hour students, nor the objectives emphasized on their Unit Tests. Consequently, these pre- and post-tests provided a method of assessing whether these two types of learning were achieved in spite of that lack of emphasis.

3) There were Evaluation questionaires completed by the students. These attempted to assess the attitudes of the students in the two sections towards the course and the instructor.

III. RESULTS

A. EVALUATION OF STUDENT POPULATIONS

In order to ascertain the relative effectiveness of the two versions of the course it was necessary to evaluate whether there was any bias built into the student populations of the two sections. It was anticipated that there might be since in previous years two tendancies had been noticed -- (1) few, if any, athletes attended the afternoon K section (it conflicted with practice) and frequently the athletes who take this course are non-science majors who come in with less-than-average preparation in mathematics, and (2) the science majors who take the course seemed to preferentially attend the morning I section (because they frequently have afternoon labs which conflict with the K-hour).

There is no need to present any detailed discussion of the populations since there was no significant difference in the distributions of any of these parameters between the two sections:

Major field (23% and 26% engineering, math, or science)
Class year (evenly distributed among the 4 years)
Prior math/science preparation (ranged from excellent to poor)
Number of other math/science courses taken simultaneously
Extra-curricular activities.

The two expected biases did not materialize to a significant degree. (1) For some reason there were only 7 athletes taking the course, and 1 of them was in the afternoon section. Two of the 7 were among the top few students in the entire course. (2) Apparently the lab conflicts were not as serious as it had appeared because the fraction of Science majors was almost exactly the same in the two sections.

The performance of the students in the two sections on the pre-test were essentially identical. Table 1 summarizes the results. Students were not required to return the pre- and post-tests, although they were told that instructor wanted them in order to evaluate how well he was teaching. Also, the students were told not to guess if they did not know an answer.

From Table 1 one can see that there is not any significant difference in the performance of the two groups of students, confirming that the two populations are essentially identical. The percentage of Tests returned was not statistically different either.

B. EVALUATION OF RELATIVE MERITS OF THE NEW COURSE VERSUS THE OLD

The relative merits of the two courses may be seen in part by observing the emphasis in the types of questions on the Unit Tests and the nature of the assignments in the Study Guide.

The percentage of the occurance of each Question type is given in Table 2 for each version of the course each of the two semesters. There was a significantly greater emphasis of application of concepts (Q.T. 6) in the new

K-hour section. The percentage of recall questions was not negligible however, and this reflects the instructor's difficulty in shifting his way of thinking. In a second iteration of writing these course materials, more discipline will be required to weed out the recall questions.

It was surprising at the end to discover the low percentage of questions which tested math skills (Q.T. 2) in the K hour, particularly in the second semester. Upon reflection it was clear that this type of tabulations of the UMT questions is very misleading. The activities of the students in many of the Units were quite mathematically oriented; however, as was mentioned in section II.B, the UMT questions were usually designed to verify that the student had done the activities assigned. Often a question would be classified as Q.T. 6, although the student may have had to do some math in order to complete the activity. This effect is a significant one in that it distorts interpretations in an unclear way. Again, in a second iteration to perform this type of comparison, a more careful way of classifying questions and responses should be developed.

The performances of the students in the two groups were remarkably similar. There were differences which are statistically significant, but not overwhelmingly so.

The first difference which became apparent was the attrition rate. Rice University has a registration procedure in which the student does not make a final registration until the end of the second week of classes. There is no penalty for dropping a course before the end of the tenth week (of a 15 week semester). Consequently, it is not unusual to have a large number of students attend a class in the early part of the semester but not continue to the end to receive a grade.

Table 3 shows the history of the numbers of students in each of the sections of the course during the first semester. The percentages are normalized to the number who stayed and received a grade. Clearly the students in the K-hour perceived the course to be less attractive in some way. The most likely interpretation is that the students in the K-hour perceived that course as being either more difficult or less interesting. It is interesting that the percentage of A's in the two sections were identical indicating that the level of difficulty of the two versions was probably comperable. There was a significantly greater percentage of students in the K-hour who elected to take the course on a pass-fail basis rather than for a grade. Since this is the path commonly taken by students who have an interest in a subject but are afraid the course is

difficult, one may conclude that students perceived the K-hour course to be more difficult than the older I-hour course.

From other kinds of evaluation information it is ambiguous whether or not there was a real difference in level of dificulty or only a perceived difference. For example, the average number of Unit Tests taken per Unit passed were identical in the first semester for the two sections. On the other hand, the K-hour course was new and had "bugs", but the I-hour course was well ironed-out. Consequently, the K-hour Units were uneven in difficulty. In particular the third, fourth, and fifth units of the first semester were considerably more difficult than the average, and that may account for the large attrition at the K-hour. If so, it suggests that all differences found between the two sections may be artifacts created by the significantly different degrees of "debugging" which the two versions have undergone. It may be completely meaningless to compare the results of the two sections in this first year of operating the new version of the course. It is certainly true that the new version will be substantially revised before being used again, so the comparisons of the first year's operation become totally academic anyway.

A significantly lower percentage of students in the K-hour continued into the second semester (the 43% continuation observed in the I-hour is typical of the previous years of operation of the course). The percentage which volunteered to be Tutors next year was only slightly lower at the K-hour. These two facts represent real measures of "student interest" and one can conclude it was somewhat lower at the K-hour. Again, it is <u>not</u> true that this difference can be attributed to the <u>designed</u> difference between the two courses; it is probably largely due to the bugs in the K-hour course.

In spite of these reservations, the performance of students in each section were analyzed for each Question Type. Table 4 shows the percentage of correct answers and the significance computed from two-by-two contingency tables. The K-hour students performed significantly better on the type 2 questions (math) and marginally better on the type 6 questions (concept application). Although the <u>numbers</u> are statistically significant, the two sets of questions upon which the numbers are based were independent and may well not be equivalent.

A less biased evaluation is made from Table 5 which shows the combined results of the scores on the pre- and post-test given at the end of the first semester and another

given at the end of the second semester. The identical tests were taken by the two sections. On the other hand, the content of the two courses varied somewhat, so it is not clear that the students in the two sections received the same preparation for the questions asked.

There was no difference between the two sections in their performance on questions of type 2 and 4. The difference seen for questions of type 6 is not significant, especially in light of the uncertainty mentioned in the previous paragraph.

Finally, we compare the scores on the pre-test and post-test by comparing Tables 5 and 1. There was a significant improvement for both sections in percentage of correct answers to Question Type 4 (recall knowledge of astronomy), so both sections learned essentially the same amount of material. There was no perceptable difference in the math skills, but probably the tests were not sufficiently difficult to provide a meaningful discriminant, and this is probably a series defect in the tests since development of math skills was one of the objectives of the project. There were no Type 6 questions (concept application) on the pre-test.

There were as many students in the second semester who had not taken the first semester as there were continuing students. There was no perceptable difference between the performance of the two groups on the post-tests given at the end of the second semester. This suggests that the previous semester's experience in the course did not significantly influence the learning behavior of the students who continued for the second semester. Interpretations of this are fraught with pitfalls since there are strong selection effects at work. For example, the students who take the second semester tend to be those who received the higher grades in the first semester.

C. STUDENT ATTITUDES

The attrition rate discussed earlier is one indicator of student attitudes towards the two versions of the course. Another measure is the answers given on Evaluation questionaires which students completed at the end of each semester.

Table 6 gives a summary of some of the results of these Evaluations. Questions were to be answered on a scale of "1" to "5" with "3" denoting neutral. The questions are listed together with the definitions given for "1" and "5".

The distributions of the number of "1", "2", etc. were tested for significant differences between the two sections, and for all of the questions in Table 2 there were no differences significant at the 5% level. Typically the probability of obtaining from two equivalent populations a more extreme difference than that observed was 0.15 to 0.95. In spite of this formal statistical result, it is interesting that the average scores shown are consistent with the conclusions drawn previously -- specifically, that the two courses were viewed to be essentially the same, but the K-hour version seemed a little more demanding (questions 2c, 2d, 3e, and 3f).

There is a suggestion that the K-hour students did not like the format of the K-hour Units as well as those in the I-hour. They would have rather had fewer exercises and more emphasis on memorization of material (3g and 3h) and they expressed less of a liking for self-paced courses in general (3b). They did not feel they had learned as much (2e) nor that what they had learned was as valuable or exciting (2a and 2b). Their overall rating of the Instructor was lower (1a through 1e), except for style!

At this point there is no way to accurately evaluate the factors which generated these generally negative expressions regarding the K-hour course. In part it can be a reaction against the format of the units. Students perceive they have learned something if they deliberately sit down and essentially memorize a body of information and display their learning on a test. It is frequently not appreciated by a student that he has learned something more important when he has struggled his way through a problem on his own, even though the problem involves only a limited scope of facts. To a large extent this may be attributed to the Study Guide not spelling out what we expected the student to achieve. Although they may in fact have achieved our objectives, the students may not have felt that they achieved what they assumed to be the appropriate objective -- a large body of facts. Another negative factor may have been the rough edges in many of the Unit write ups.

D. COSTS

There are two separate items to be discussed concerning costs. First is the amount of instructor-time and graduate assistant time spent during this project. This can be divided into these 3 activities: construction of course material, operation of course, and evaluation of this project. The second is the relative costs involved in operating the two versions of this course -- materials cost,

instructor time, and Tutor's time. This gives a measure of the viability of tranfering a course similar to this new course into other contexts.

1) Instructor's Time

An attempt was made to keep accurate detailed records of the time spent by the instructor and graduate assistant on various aspects of the course and its evaluation. This was done fairly accurately through approximately the mid-point of the first semester, and done less accurately thereafter.

The instructor (the project director) has found self-paced courses (like both versions of this course) to be very time-consuming operations. Most of that time is expended in preparation of course materials (Study Guide, Unit Tests, collection of supplementary materials, etc.). Even so, the classroom time and the various administrative tasks outside of class occupy considerable time. In this project, during the semester, most of the work required to evaluate the project was handled by a graduate assistant. This included computer programming, collecting the input data, and identifying and correcting erroneous information supplied by the Tutors.

During the four weeks preceding the first semester and the first five weeks of the first semester most of the first semester course materials were generated and much of the machinery for the evaluation process was constructed. Time commitments during the remainder of the first semester (last 10 weeks) reflect revision of parts of the course material plus the time required to operate the course and operate the evaluation procedure.

Table 7 gives a breakdown of average hours per week expended for each course for various activities during these separate periods of time. The some 50 hours/week observed in the first two time periods is fairly accurate, as can be attested to by the disasterous fall off in the Instructor's scientific research program during that period and his neglect of his graduate students. The great bulk of the time was in the preparation of the course material for the new course. No modifications were made to the old one. The operation of the K-hour version required about double the time required by the I-hour version. This is partly due to the attention required when problems arose with the new course material; however, the structure of the activities of the students in the K-hour version was such that more time will be required even when the problems are ironed out. It is estimated that if both sections were run simultaneously

using a debugged version of the K-hour course, the total time commitment for the two sections would be around 12 hours per week. With the old I-hour version it would be about 8 hours per week to operate the two sections.

During the second semester records of time were not accurately maintained, however, they were roughly the same. About a third of the K-hour course material for the second semester was generated during the latter portion of the first semester. The remainder was done during the second semester, keeping ahead of the fastest students.

The time requirements for operating the K-hour version are significantly greater than for the I-hour version, but -- at least in the present environment at Rice -- it is not an unreasonable amount. The greatest problem with the project as it was run was the simultaneous requirement of (a) creating the course material, (b) operating essentially two separate courses, and (c) the other obligations of the Instructor.

2) Tutors

The Tutor's at the K-hour were heavily loaded down with 6 to 8 students each. The I-hour course has operated successfully with up to 12 students per Tutor. Some of the extra time required at the K-hour was due to inadequate Study Guides. A large amount, however, was due to the nature of the Unit Matery Tests and other items which the Tutors had to check. By revising the Units it will be possible to reduce the load somewhat (this in fact was done in designing the second semester), but some difference will remain.

The costs of having Tutors for any self-paced course are costs not incurred in, e.g., lecture courses. Consequently the hurdle of arranging to have Tutors at all is the main hurdle an Instructor would have to face to implement this type of course. If the Tutors had to be paid money, then the load per tutor might become an important factor. By the system of awarding course credit one does not face a rigid constraint, and so the extra load per Tutor is easily overcome (provided one has a sufficient supply of interested students). We have been successful with the use of students drawn directly from the class and used as Tutors. In this case there is no cost at all, monetary or credit.

3) Materials Cost

A course operated like the I-hour version requires each student to purchase a textbook and the Instructor-prepared Study Guide. We have charged for our Study Guide and usually break even. The Department has borne the cost of reproducing the many copies of Unit Tests and miscellaneous materials.

The materials cost in the K-hour course are more complex to retrieve. The K-hour Study Guide contained considerably more supplementary material than the I-Hour Study Guide. This could be recouped by selling the Study Guide, and thus the total cost to the student would be larger if he were to also purchase a text. Our experience was that students wanted a text (our Study Guide was not meant to be as complete as a text). Because the Unit activities frequently stretched the student beyond what they knew, they would go to a text and were very disatisfied with any but the most comprehensive one (the Abell text) which is, of course, the most expensive one. Consequently, unless the Study Guide were expanded to be a completely self-contained unit, one should plan on the student also buying a good text.

There were large amounts of copying done in order to provide several copies of crucial papers, catalogues, etc. for use by students in the library. These costs plus the usual costs of reproducing Unit Tests, etc. either have to be borne by the Department or have to be recouped by profits on the Study Guide. Many of those costs would be one-time costs.

It is difficult to give a precise amount for the copying done which falls into these categories. The following is an estimate of the expenditures for the two semesters of the K-hour course (excluding the Study Guides):

a) 20 copies each of 4 versions of Unit Tests for 17 Units each semester	2720 p.
b) 5 copies each of 3 booklets made up of articles, catalogues, tables, etc. Two booklets were approximately 100 p.; one booklet approximately 250 p.	2250 p.
	4970 p.

This plus miscellaneous copying amounted to between 5000 and 6000 pages of copying in addition to the Study Guides. At typical cost of 4¢/page one must be prepared to spend some $200 to $300 in order to implement the course as we structured

it. The exact cost would vary with the numbers of students, Tutors, etc.

IV. CONCLUSIONS

The new course developed in this project was designed to fulfill the Instructors educational objectives in a more ideal fashion than the older traditional Keller course was doing. The new course did that, with the exception of various minor problems typical of a course the first time through.

The evaluation of the student's performance in these two courses shows that they learned essentially identical amounts. It was not possible to demonstrate that the new course -- as it operated this first time -- was any better than the older one.

The costs of operating the new course were roughly double the costs of operating the old one, but much of that extra time can be attributed to it being the first year of operation. The cost of developing the course material for the new course was large. Whether larger than for developing any other type of course is not possible to evaluate since so many individual factors enter. The work probably approached that of an Instructor writing a textbook for a course that he was teaching.

V. FUTURE

In the next academic year this introductory astronomy course will undergo some revision. For the present we will not attempt to continue to develop the new format for use as a two semester introductory course for non-science students. Instead, we plan to consolidate into a one semester course the basic material contained in last year's two semester course. This will be taught using the Abell textbook and a new Study Guide for it which is similar to that used before, though we have completely revised it with improvements drawn from the experience with the K-hour version developed last year.

The second semester of the course will be operated in a format similar to the K-hour version last year. By using the text in the first semester, it will allow students to initially have a clearly structured course with a coordinated text and Study Guide with well defined knowledge and skills defined. With this background, the second semester will be entirely devoted to topics with

considerable depth, and in that course we will not have to be concerned with developing basic vocabulary and skills at the same time.

In practical terms this means that much of the course material developed last year for the K-hour course will be used for the second semester, but many of the basic foundation units will be discarded because they essentially only duplicate the content of the Text.

This second semester course will be totally self-contained course using exercises, library materials, etc. It will, however, not be a first course for non-science students which was our original goal. It is a practical route to procede since it will mean that we will have a firmly set first semester course which will require the minimal amount of time to operate and maintain the course materials. This will allow us to continue to devote the time required to experiment with and develop the one second semester course. After the experience gained with the second operation of these activities we expect that this course will be developed to the point where it might be used by other instructors at other institutions.

Table 1

RESULTS OF PRE-TEST

	I-Hour #	I-Hour %	K-Hour #	K-Hour %
Tests Returned	44	63	20	69
Questions Returned				
Q. Type 2	528	100	240	100
4	528	100	240	100
Questions Answered				
Q. Type 2	447	85	207	86
4	378	72	161	67
Questions Right				
Q. Type 2	377	66	183	76
4	145	27	72	30

Q. Type 2: Mathematical Skills
4: Recall knowledge of astronomy facts.

The percentages for the question types based upon the number of questions of that type returned in each section.

The only pre-tests tabulated were those of the students who received grades in the course.

Table 2

PERCENT OF QUESTIONS OF EACH TYPE
ON THE UNIT TESTS

	Question Type		
	2	4	6
SEMESTER 1:			
Hour: I	13%	54%	33%
K	19	28	53
SEMESTER 2:			
Hour: I	17	54	29
K	11	38	51

Question Type 2: Math skills
4: Recall knowledge of facts
6: Ability to apply concepts.

Table 3

HISTORY OF NUMBER OF STUDENTS
FIRST SEMESTER

Time point	I-Hour		K-Hour	
	#	%	#	%
1. Showed up at least once	70	125	50	172
2. Registered at two weeks	67	120	39	134
3. Took at least one Unit Test	62	111	36	124
4. Remainder and received grade	56	100	29	100
Grades: 5 (fail)	6	5	2	7
4 (pass)	11	20	11	38
3 (C)	4	7	0	0
2 (B)	9	16	1	3
1 (A)	29	52	15	52
5. Continued to take second semester course	24	43	8	28
6. Volunteered to be Tutor next year	6	11	2	7

Table 4

PERFORMANCE ON UNIT TEST
QUESTIONS TABULATED BY
QUESTION TYPE AND SECTION

Question Type	I-Hour	K-Hour	Significance*
2	88%	93%	0.0088
4	93	94	0.41
6	90	93	0.035

* The significance is the probability that this (or a more extreme) difference between the I-Hour and K-Hour figures would have occurred by chance if the two classes were identical.

Table 5

PERFORMANCE ON POST-TEST

Question Type	I-Hour	K-Hour	Significance*
2	81%	81%	0.95
4	71	72	0.98
6	61	73	0.076

* See Table 4 footnote.

These percentages are to be compared with the "Questions right" percentages in Table 1.

Table 5

STUDENT ATTITUDE RESPONSES

Question	1 =	5 =	Average Score I-Hour	K-Hour
1. Student's overall rating of Instructor's:	Excellent	Poor		
a. Presentation of Materials			1.78	2.85
b. Approach to student participation and interaction			1.84	2.00
c. Style			2.31	1.50
d. Requirements and Evaluation of Students			1.56	2.20
e. Teaching Effectiveness			1.80	2.64
2. Student's rating of course:				
a. Subject matter was extremely	valuable	useless	2.50	3.00
b. Subject matter was extremely	exciting	boring	2.33	3.07
c. Subject matter was extremely	demanding	trivial	2.67	2.00
d. Workload was	very high	very low	2.80	1.93
e. Amount learned	most of that presented	very little	1.84	2.64

Table 6 (Continued)

Question	1 =	5 =	Average Score I-Hour	K-Hour
3. a. the number of Units in the course were:	much too many	much too few	2.44	2.50
b. Attitude toward self-paced courses:	like very much	dislike very much	1.77	2.37
c. Has the course helped you academic self-discipline?	Yes, very much	No, it hindered	2.01	1.96
d. was the amount of material covered:	far too little	far too much	3.06	3.07
e. was the depth of coverage:	Hot deep enough	too deep	3.01	3.21
f. should the course have:	much less math	much more math	2.94	2.79
g. should the course have:	much less memorization	much more memorization	2.35	2.77
h. should the course have more learning by doing exercises, labs, etc?	Yes, very much.	No, just the opposite.	2.72	3.34

Table 7

TIME REQUIREMENTS BY INSTRUCTORS AND ASSISTANT. AVERAGE HOURS PER WEEK SPENT BY TIME PERIOD.

		Instructor			Assistant
	Course Material Preparation	Course Operation		Course Evaluation	Course Evaluation
Time Period	K only	I	K	I + K	I + K
4 weeks preceeding semester	42.9	-	-	5.8	43.8
first 5 weeks of semester	38.2	4.8	9.8	-	12.0
last 10 weeks of semester	10.0	4.0	9.0	-	4.0

Appendix A -- From old version

UNIT 8

ASTRONOMICAL INSTRUMENTS

Overview:

Astronomy is an observing science rather than an experimental one. Naturally, observing instruments play a central role in the subject. In this unit we will learn something of the nature of the devices used--in particular, their advantages and limitations.

1. Procedure (P):

Read 11.1. Carefully study Figures 11-2 and 11-4.

Objective (O):

Be able to describe or correctly use the following: objective, focus, focal length, focal plane. Be able to show how focusing can occur through reflection or refraction.

2. P:

Read 11.2. Study the equations.

O:

(a) You need not memorize the constant coefficients in the equations, but you should memorize the proportionalities involved--e.g., image scale is proportional to the focal length ($s \propto f$).

Very crudely, the focal length f is proportional to the length of the telescope tube. The diameter d is the number one commonly hears mentioned, as "He used the 200 inch telescope" refers to 200 inch diameter mirror. By the insertion of various mirros, etc., one can change the focal length of a telescope to longer or smaller values. One can only decrease the diameter--by putting masks over the mirror, for instance.

Know that the size of the image depends on the focal length only, whereas the brightness of the image (and hence the exposure time required) depends on diameter divided by focal length. Know the formula on p. 224 and how to use it.

(b) Work problem 1 and 2, p. 248. (answers at end of unit)

A. Estimate the focal length of the eye. Estimate the size of the disk of the moon ($1/2^{\circ}$) on the retina.

B. Estimate the ratio of the brightness of an image at the retina with the brightness at the focus of the 200 inch telescope.

C. Estimate the ratio of the angle which can be resolved by the eye to that by the 200 inch telescope.

3. P:

Read 11.3 and 11.4

O:

Be able to explain the advantage of a reflecting telescope over a refracting telescope with respect to chromatic aberration.

4. P:

Read 11.5. Do not memorize the focus arrangements in Figure 11-14, but do study them.

Q:

(a) Be able to explain why it is easier to get at the focus of a refractor telescope than a reflecting. What devices are necessary for most reflectors?

(b) Be able to discuss the relative advantages and disadvantages of refractors and reflectors.

(c) Know the location and size of the largest existing reflector and refractor.

5. P:

Read 11.6.

Q:

(a) Be able to discuss at least two ways astronomers use telescopes other than "looking through" them.

(b) What is most observing time on large telescopes used for? On a telescope of fixed size, would it take longer to photograph a star as a point of light or to photograph its spectrum?

(c) Be able to sketch a simple reflector and a simple refractor (Fig. 11-19) and be able to indicate where one would attach a simple prism spectrograph (Fig. 11-20) or an objective prism.

6. P:

Read 11.7.

Q:

Be able to list and briefly describe at least three of the limitations imposed by the air.

7. P:

Read 11.8 and 11.9.

Q:

(a) Be able to explain why radio telescopes are usually so much larger than optical ones. (There are two reasons - know both.)

(b) Is radio affected by the atmosphere like optical?

(c) What are the reasons for putting UV and x-ray telescopes on rockets or satellites?

8. P:

Give a mini-lecture. Be sure you discuss the exercises and can sketch the reflector and refractor.

_____

Listener's Name

9. P:

Take a written mastery test.

Answers to Exercises

1. (5.75 in, same), 2. (4 sec.)

A. $f \sim 1$ in, so $s \sim 1/2 \times 0.01744 \times 1$ in. $\approx .0087$ in.

B. A of eye $\sim 1/8$ in., so $\frac{B(\text{eye})}{B(200\text{ in.})} \sim \left(\frac{1/8}{1}\right)^2 \Big/ \left(\frac{200}{660}\right)^2 \sim 0.17$

C. $\frac{\alpha(\text{eye})}{\alpha(200'')} = \left(\frac{1}{1/8}\right) \Big/ \left(\frac{1}{200}\right) = 1600$

Appendix B -- From new version I-5/1

UNIT I-5 TOOLS OF THE TRADE

Objectives:

In this Unit you will ascertain the uses of various astronomical instruments and especially the relative advantages and disadvantages of various kinds of instruments.

Furthermore, in this Unit you will develop a technique of asking questions as a test of your knowledge, rather than answering.

Procedures:

1. First study Hodge Chap. 6 and 7. You should be able to describe each of the following: refracting and reflecting telescopes, magnifying power, light-gathering power, resolving power, equatorial and azimuthal mounts, camera, photometer, and spectrograph.

2. Remember, in addition to the Unit Mastery Test for this Unit, to pass this Unit you must satisfactorially do and turn in the Lab Exercise which was included in the last Unit.

3. Implicit in the discussion of Section 6-3 there are three equations which are useful in order to make quantitative statements about telescopes. You should study the discussion and Exercises attached (A). There is also included a discussion of the factors which determine the size of an image produced by a telescope.

4. Attached as part B of this Unit there is a scenario in which you take the part of an astronomer visiting an observatory to do some observation work. There is outlined an Exercise which you should go through. The UMT for this Unit consists of your acting through this scenario with your Tutor. You may wish to go through this Exercise with another student in order to prepare for the UMT. When you feel you are ready, see your Tutor. Turn in your Lab at that time. During the UMT you may use your text, Study Guide, or your own notes.

In addition, there will be some Evaluation questions asked. For these, no books, notes, or any other aides are allowed - and of course, they do not count as a grade in any way - it is merely a check of my own to see if I have been successful in teaching you. Please answer conscientously - Thank you.

A. Telescope features; Exercises. I-5/A1

1. Magnifying power: $M = F_o/F_e$

F_o is the focal length of the objective.

F_e is the focal length of the eyepiece.

Example 1. The magnification of the 200-inch Palomar telescope (F_o = 660 inches, not 700 inches as given in the text) with eyepieces of focal length 4 inches, 1 inch, and 1/2 inch are respectively M = 165, 660 and 1320.

2. Light-gathering power:

Amount of light gathered is simply proportional to the collecting area, the area of the objective. Since telescopes are usually circular, the area is $(\pi/4)d^2$ where d is the diameter of the objective.

Usually one speaks of a telescope as having a light-gathering power which is so many times that of another instrument. A natural convenient reference instrument is the human eye which has a diameter of about 1/3 inch.

Example 2. A telescope with diameter d inches has a light-gathering power relative to the eye of $[d/(1/3)]^2 = 9d^2$. The largest refractor (Yerkes Observatory) has a diameter of 40 inches, so it collects 14,400 times as much light as the eye.

Exercise 1. Compute the light-gathering power of the Palomar 200-inch telescope relative to the Yerkes refractor.

3. Resolving power: R

The resolving power is a measure of the ability of a telescope to delineate fine angular structure. The smearing of fine structure is due to diffraction (Fig. 6-27). The smallest angular structure which can be distinguished with a telescope of diameter d is

$$R = 2.3 \times 10^5 \lambda/d$$

where λ is the wavelength of the radiation, and R is measured in units of seconds of arc. Note: to use this equation, λ and d must be expressed in the same units.

Example 3. The eye is most sensitive to light with λ = 5000 Å = 5 x 10^{-5}cm. So, R $\approx$ 4.5/d, so a 5-inch telescope is sufficient to resolve stars 1" apart.

Exercise 2. Compute R for the 200-inch telescope for ultra-violet ($\lambda \approx$ 1000 Å), visible (5000 Å), and microwave radio (1 cm). (Easiest to first convert 200 inches to cm.)

4. Exercise 3. Here is a specification for the requirements of a new telescope:

Resolving power at 1000 Å must be such that stars separated by 0.02" (or closer) can be resolved.
Light-gathering power must be at least 9 x 10^4 times eye.

Compute the diameter required by each of these requirements. The diameter required must be the larger of the two.

Exercise 4. Here is a design problem. You need a telescope which has the following characteristics:

Light-gathering power = 900 times eye.
Magnifying power = 80 times (with 1/2-inch focal length eyepiece).
No chromatic aberration.
It will not be used for astronomical work; will be used to take photographs of birds and so you want a mounting to easily follow them.

Figure out the specifications for the telescope -- size of objective, focal length, type (mirror or lens; if lens, what kind), and type of mounting.

5. A topic not discussed by the text is the size of an image obtained with a telescope. To take a photograph one would place a piece of photographic film at the focus (see Fig. 6-4, 6-9). The size of the image is proportional to the angular size of object being photographed and proportional to the focal length of the objective F_o.

If the angular size of the object is α° (meaning you express the angle in units of degrees) then the image size S is given by

$$S = 1.7 \times 10^{-2} F_o \alpha^\circ$$

where S and F_o are expressed in the same units.

Example 4. The moon has an angular diameter of $31' \approx 1/2^{\circ}$. For the 200-inch telescope, the diameter of the moon at the prime focus is

$$1.7 \times 10^{-2} \times 6.6 \times 10^{2} \times 1/2 \approx 5.6 \text{ inches.}$$

Exercise 5. The Palomar 48-inch Schmidt camera has a focal length of 120 inches. Compute the diameter of the image of the moon and the image of Jupiter. (When Jupiter is closest to the earth, its angular size is about 45".)

When discussing point sources of light, the image size is important in describing the separation of the sources, but the brightness of the points themselves do not depend on the focal length, only upon the diameter.

On the other hand, if one has an extended source of light, like the finite disk of a planet, then the light of the image is spread out over an area proportional to the image size squared -- S^2. Since for a given angular-size object, $S^2 \propto F_o^2$, then the brightness of an extended object, B, is given by

$$B \propto (d/F_o)^2.$$

The ratio F_o/d is called the "focal ratio" or simply the "f ratio", it is the ratio of the focal length of the lens to the diameter of the lens. A typical 35-mm camera has a lens in which the f ratio can be varied -- usually from around 2.8 to about 16 (these are expressed compactly by f/2.8 to f/16). The smaller the f ratio, the brighter the image. With a brighter image you can obtain the same photograph with less exposure time; hence a low f-ratio lens is said to be "faster".

So, we see that to fully describe a telescope we need more information than just the diameter. We need the focal length, or equivalently the f ratio.

The f ratio of the 200-inch Palomar telescope is 660/200 = 3.3. The f ratio of the 48-inch Schmidt telescope is 120/48 = 2.5. Hence, the 48-inch has a brighter image! It is faster even though of smaller diameter! How much faster? The ratio of brightnesses is

$$B_{48}/B_{200} \approx (1/2.5)^2/(1/3.3)^2 \approx 1.7.$$

So, the 48-inch image is almost twice as bright as the 200-inch image.

You may wonder "What is the advantage of the larger telescope if the smaller one has the brighter image?" The answer is two-fold: (1) The 200-inch image size is larger by a factor of 660/120 = 5.5; so, it is more useful if you want photographs with small detail. Note this consideration has nothing to do with the 200-inch diameter, it depends only upon focal length. (2) The total light-gathering power of the 200-inch is greater by $(200/48)^2 \approx 18$; so, it can see much fainter point sources. So, the relative usefulness of telescopes of different sizes depends upon the use involved.

B.

On the following page is a scenario in which you take the role of an astronomer visiting an observatory to do some work.

There is a list of observational projects there, and you should go through the list and think about the following question for each.

If you were going to do this observation, what would be the desired features of a telescope for this job? (Would you want high magnification or low? Large image scale or small? etc.)

As an Exercise, you should go through the list and make a list of the desired features for each and the questions you would use to ask about telescopes in order to find the most appropriate one to use and the equipment to use with them.

The Unit Mastery Test will consist of your acting out this scenario with your Tutor taking the role of the Administrative Assistant to the Director of the Observatory. The Administrative Assistant is not an astronomer, so he can not help you decide what you need -- he can only give you basic information about the instruments. For example, you can not ask if a telescope has a large image scale; you may ask for the focal length and thereby figure out for yourself the suitability of the image scale. Your Tutor will pick two of the listed observations, or devise new ones, for you to assume as your projects for the UMT. Your task is to ask you Tutor questions (as though he were the Administrative Assistant) and on that basis pick out the best telescope and associated equipment for each observational project. You must be able to explain why you make each choice.

Note: One of the constraints upon choosing the most appropriate telescope may be the availability of the telescope. The most powerful telescopes are reserved for only those projects which absolutely require their use. If a project can just as easily be done with a smaller telescope, then the smaller one is the proper one.

You should probably create a table of information for the telescopes as you acquire it from your Tutor. This will make it easier to compare the telescopes to make the best choice. This information on the required telescopes, as well as any notes or computations involved in doing the UMT, should all be put on a UMT answer sheet which is then eventually turned in when you complete the UMT. Remember, you should not discuss the specific properties of the telescopes with other students.

Telescope Selection Scenario

You are an astronomer and you have just arrived at the Skyhigh Observatory in the Chilean Andes at 13,000 feet altitude. There are several telescopes available; they are named after famous astronomers:

The Bradley	The Hubble #1
The Flamsteed	The Hubble #2
The John Herschel	The Newton
The Wm. Herschel	The Baade
The Shapley	

The Skyhigh Observatory is very new, and they are not yet well organized. In particular, they have not yet prepared any descriptions of the characteristics of each telescope or the instruments available on each. The Director of the Observatory is unavailable, but you need to reserve time on one or more telescopes so you can get your work done. The only available source of information on the instruments is the Administrative Assistant to the Director who knows nothing about astronomy himself. He does have a file which contains just the bare physical facts about each telescope, and you can ask him for it.

Here is a list of observational projects which you might want to pursue.

1. A series of color photographs of Mars taken every night for a month; want images as large as possible.
2. A series of photographs taken every night for a week of a patch of sky 6° on a side. Want one image per night on film of about 10 inches on a side.
3. A series of photographs taken every night for three months of a very large patch of sky -- about 30° on a side. If necessary, can take up to 10 photographs per night to cover the area, but no more. Important aspect is the continuous nightly coverage; not concerned about very faint stars.
4. There is a fuzzy extended patch of sky, about 1/10° in diameter, very very faint. You want a picture as bright as possible. Ideally the image size should be about an inch or larger.
5. There is an extremely faint point source. You want to analyze its chemical composition in detail.
6. You want a very detailed chemical analysis of a very small patch of the solar surface.

7. You want a very accurate measurment of the brightness of each of a group of very, very faint stars. They are in an area of the sky about 1/10" in diameter.
8. You want an accurate measurement of the brightness of each of several moderately bright stars, measured several times each night on each night over a couple of month period.

TELESCOPES AND INSTRUMENTS AT THE SKYHIGH OBSERVATORY

Telescope	Diam.	foc. l.		Mount	Access	Instruments
BAADE	4-m	15-m	Prime focus	Equatorial	Difficult	Camera - 5 cm x 5 cm film; photometer
		60-m	Cassegrain			Camera - 5 cm x 5 cm film; photometer; Moderate dispersion spectrograph
NEWTON	1.5-m	15-m	Newtonian	Equatorial	Mod. easy	Low dispersion spectrograph
SHAPLEY	1.3-m	2.6-m	Schmidt	Equatorial	Difficult	Camera - 40 cm x 40 cm film
FLAMSTEED	1-m	15-m	Single lens refractor	Equatorial	Mod. easy	Camera - 12 cm x 12 cm film; moderate dispersion spectrograph
BRADLEY	75-cm	12-m	Achromatic refractor	Equatorial	Easy	Camera - 12 cm x 12 cm film; moderate dispersion spectrograph
HUBBLE #1	36-cm	60-cm	Schmidt	Equatorial	Easy	Camera - 10 cm x 10 cm film
HUBBLE #2	36-cm	60-cm	Schmidt	Equatorial	Easy	Camera - 10 cm x 10 cm film; 4^{o} objective prism
Wm. HERSCHEL	30-cm	45-m	Reflector	Heliostat	Difficult	Photometer; high dispersion spectrograph; narrow-band interference filters
John HERSCHEL	30-cm	4.5-m	Cassegrain	Equatorial	Easy	Photometer